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Claims

1. An apparatus for applying at least one electrical contact to a semiconductor substrate, comprising:

at least first and second rotatable applicator rolls, said first rotatable applicator roll being rotatable about a first axis, said first rotatable applicator roll comprising a first roll printing surface, said first roll printing surface comprising at least one raised first pattern surface, each said raised first pattern surface being positioned such that upon rotation of said first rotatable applicator roll about said first axis, each said raised first pattern surface passes through a first printing space, whereby a first semiconductor substrate surface of a semiconductor substrate passing through said first printing space while said at least one raised first pattern surface is covered with a first conductive ink and said first rotatable applicator roll is being rotated will come into contact with said first conductive ink on at least a part of said raised first pattern surface, and will not come into contact with first conductive ink on substantially any of said first roll printing surface other than said raised first pattern surface, such that a first conductive ink pattern will be deposited on said first semiconductor substrate surface; and

at least a first conveyor which is operable to convey a semiconductor substrate to said second rotatable applicator roll after said semiconductor substrate passes through said first printing space,

said second rotatable applicator roll being rotatable about a second axis, said second rotatable applicator roll comprising a second roll printing surface, said second roll printing surface comprising at least one raised second pattern surface, each said raised second pattern surface being positioned such that upon rotation of said second rotatable applicator roll, each said raised second pattern surface passes through a second printing space, whereby said first semiconductor substrate surface of said semiconductor substrate passing through said second printing space while said raised second pattern surface is covered with a second conductive ink and second rotatable applicator roll is being rotated about said second axis will come into contact with said second conductive ink on at least part of said raised second pattern surface, and will not come into contact with second conductive ink on substantially any of said second roll printing surface other than said raised second pattern surface, such that a second conductive ink pattern will be deposited on said first semiconductor substrate surface.

2. An apparatus as recited in claim 1, wherein at least one region of said first conductive ink pattern and at least one region of said second conductive ink pattern overlap by less than 1 cm.

3. An apparatus as recited in claim 2, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface, except for a border region around an edge of said first semiconductor substrate surface.

4. An apparatus as recited in claim 2, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface.

5. An apparatus as recited in claim 1, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface, except for a border region around an edge of said first semiconductor substrate surface.

6. An apparatus as recited in claim 1, further comprising at least one drying region and a second conveyor which is operable to convey said semiconductor substrate to said at least one drying region after said semiconductor substrate passes through said second printing space.

7. An apparatus as recited in claim 1, further comprising a first drying region, said first conveyor being operable to convey said semiconductor substrate continuously through said first drying region and then to said second rotatable applicator roll.

8. An apparatus as recited in claim 7, wherein said first drying region comprises at least one gas jet which is operable to direct a stream of gas toward said first conductive ink pattern.

9. An apparatus as recited in claim 7, further comprising a second drying region and a second conveyor,

said second conveyor being operable to convey a semiconductor substrate to said second drying region after said semiconductor substrate passes through said second printing space.

10. An apparatus as recited in claim 7, further comprising a second drying region, a second conveyor and a second surface printer,

said second conveyor being operable to convey said semiconductor substrate to said second drying region and then to said second surface printer after said semiconductor substrate passes through said second printing space,

said second surface printer being operable to provide a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

11. An apparatus as recited in claim 10, wherein said second conveyor is operable to convey said semiconductor substrate continuously through said second drying region and then to said second surface printer.

12. An apparatus as recited in claim 1, further comprising a second surface printer, said second surface printer being operable to provide a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

13. An apparatus as recited in claim 12, further comprising a second surface conveyor, said second surface conveyor being operable to convey said semiconductor substrate to said second surface printer after said semiconductor substrate passes through said second printing space.

14. An apparatus as recited in claim 12, wherein said second surface printer comprises at least one second surface rotatable applicator roll, said second surface rotatable applicator roll comprising a second surface roll printing surface, said second surface roll printing surface comprising at least one raised second surface pattern surface, each said raised second surface pattern surface being positioned such that upon rotation of said second surface rotatable applicator roll, each said raised second surface pattern surface passes through a second surface printing space,

whereby said second semiconductor substrate surface of a semiconductor substrate passing through said second surface printing space while said second raised second surface pattern surface is covered with a second surface conductive ink and said second surface rotatable applicator roll is being rotated will come into contact with said second surface conductive ink on at least part of said raised second surface pattern surface, and will not come into contact with second surface conductive ink on substantially any of said second surface roll printing surface other than said raised second surface pattern surface, such that a second surface conductive ink pattern will be deposited on said second semiconductor substrate surface.

15. An apparatus as recited in claim 12, wherein said second surface printer comprises at least one screenprinter.

16. An apparatus as recited in claim 12, wherein said second surface printer comprises at least one fine-line dispenser.

17. An apparatus as recited in claim 12, further comprising at least one firing furnace and a third conveyor,

said third conveyor being operable to convey said semiconductor substrate to said at least one firing furnace after said second surface printer provides said second surface contact on said second semiconductor substrate surface.

18. An apparatus as recited in claim 1, further comprising a second surface printer and a second conveyor,

said second surface printer being operable to provide a second surface contact on a second semiconductor substrate surface of said semiconductor substrate,

said second conveyor being operable to convey said semiconductor substrate to said first printing space after said second surface printer provides said second surface contact.

19. An apparatus as recited in claim 18, wherein said second surface printer comprises at least one second surface rotatable applicator roll, said second surface rotatable applicator roll

comprising a second surface roll printing surface, said second surface roll printing surface comprising at least one raised second surface pattern surface, each said raised second surface pattern surface being positioned such that upon rotation of said second surface rotatable applicator roll, each said raised second surface pattern surface passes through a second surface printing space, whereby said second semiconductor substrate surface of a semiconductor substrate passing through said second surface printing space while said raised second surface pattern surface is covered with a second surface conductive ink and said second surface rotatable applicator roll is being rotated will come into contact with said second surface conductive ink on at least part of said raised second surface pattern surface, and will not come into contact with second surface conductive ink on substantially any of said second surface roll printing surface other than said raised second surface pattern surface, such that a second surface conductive ink pattern will be deposited on said second semiconductor substrate surface.

20. An apparatus as recited in claim 18, wherein said second surface printer comprises at least one screenprinter.

21. An apparatus as recited in claim 18, wherein said second surface printer comprises at least one fine-line dispenser.

22. An apparatus as recited in claim 18, further comprising at least one firing furnace and a third conveyor,

said third conveyor being operable to convey said semiconductor substrate to said at least one firing furnace after said semiconductor substrate passes through said second printing space.

23. An apparatus for applying at least one electrical contact to a semiconductor substrate, comprising:

at least a first tank, said first tank containing a first conductive ink comprising a hot melt ink; and

at least a first rotatable applicator roll, said first rotatable applicator roll being rotatable about a first axis, said first rotatable applicator roll comprising a first roll printing surface, said first

roll printing surface comprising at least one raised first pattern surface, each said raised first pattern surface being positioned such that upon rotation of said first rotatable applicator roll about said first axis, each said raised first pattern surface passes through a first printing space, whereby a first semiconductor substrate surface of a semiconductor substrate passing through said first printing space while said raised first pattern surface is covered with said first conductive ink and said first rotatable applicator roll is being rotated will come into contact with said first conductive ink on at least part of said raised first pattern surface, and will not come into contact with first conductive ink on substantially any of said first roll printing surface other than said raised first pattern surface, such that a first conductive ink pattern will be deposited on said first semiconductor substrate surface.

24. An apparatus as recited in claim 23, wherein when said first rotatable applicator roll is rotated about said first axis, each said raised first pattern surface passes through a collection space which, when said first tank contains an operational quantity of a first conductive ink, is located within said quantity of first conductive ink, such that said raised first pattern surface becomes covered with said first conductive ink.

25. An apparatus as recited in claim 23, further comprising at least a first rotatable cylindrical tank roll, said first rotatable cylindrical tank roll having an outer surface, said first rotatable cylindrical tank roll being rotatable about a first axis, such that when said first rotatable cylindrical tank roll is rotated about said first axis, said outer surface passes through a first collection space which, when said first tank contains an operational quantity of said first conductive ink, is located within said quantity of first conductive ink and said outer surface passes through a first transfer space;

each said raised first pattern surface being positioned such that upon rotation of said first cylindrical rotatable applicator roll about said second axis, each said raised first pattern surface passes through said first transfer space, such that when said first tank contains an operational quantity of said first conductive ink, said first conductive ink is transferred from said first tank to said outer surface in said first collection space, and from said outer surface to said raised first pattern surface in said first transfer space, such that said raised first pattern surface becomes covered with said first conductive ink.

26. An apparatus as recited in claim 23, wherein said first conductive ink comprises hexadecanol and silver.

27. An apparatus as recited in claim 23, further comprising a first drying region and a first conveyor, said first conveyor being operable to convey said semiconductor substrate continuously through said first drying region after said semiconductor substrate passes through said first printing space.

28. An apparatus as recited in claim 27, wherein said first drying region comprises at least one gas jet which is operable to direct a stream of gas toward said first conductive ink pattern.

29. An apparatus as recited in claim 23, further comprising a second surface printer, said second surface printer being operable to provide a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

30. An apparatus as recited in claim 29, further comprising at least one firing furnace and a firing furnace conveyor,

said firing furnace conveyor being operable to convey said semiconductor substrate to said at least one firing furnace after said second surface printer provides said second surface contact on said second semiconductor substrate surface.

31. An apparatus for applying at least one electrical contact to a semiconductor substrate, comprising:

at least first and second tanks;

at least first and second rotatable cylindrical tank rolls;

at least first and second rotatable cylindrical feed rolls;

at least first and second rotatable cylindrical applicator rolls,

said first rotatable cylindrical tank roll having an outer surface, said first rotatable cylindrical tank roll being rotatable about a first axis, such that when said first rotatable cylindrical tank roll is rotated about said first axis, said outer surface passes through a first collection space which, when

said first tank contains an operational quantity of a first conductive ink, is located within said quantity of first conductive ink, and said outer surface passes through a first transfer space;

said first rotatable cylindrical applicator roll being rotatable about a second axis, said first rotatable cylindrical applicator roll comprising a first roll printing surface, said first roll printing surface comprising at least one raised first pattern surface, each said raised first pattern surface being positioned such that upon rotation of said first cylindrical rotatable applicator roll about said second axis, each said raised first pattern surface passes through said first transfer space and each said raised first pattern surface passes through a first printing space defined between said first rotatable cylindrical applicator roll and said first rotatable cylindrical feed roll, said first rotatable cylindrical feed roll being rotatable about a third axis, said first axis, said second axis and said third axis being substantially parallel;

such that when said first tank contains said operational quantity of said first conductive ink and said first rotatable applicator roll, said first tank roll and said first feed roll are being rotated, said first conductive ink is transferred from said first tank to said outer surface in said collection space, and said first conductive ink is transferred from said outer surface to said at least one raised first pattern in said first transfer space;

whereby a first semiconductor substrate surface of a semiconductor substrate passing between said first rotatable cylindrical applicator roll and said first rotatable cylindrical feed roll through said first printing space while said first tank contains said operational quantity of said first conductive ink and said first rotatable applicator roll, said first tank roll and said first feed roll are being rotated, will come into contact with said first conductive ink on at least part of said raised first pattern surface, and will not come into contact with first conductive ink on substantially any of said first roll printing surface other than said raised first pattern surface, such that a first conductive ink pattern will be deposited on said first semiconductor substrate surface; and

at least a first conveyor which is operable to convey a semiconductor substrate to said second rotatable applicator roll after said semiconductor substrate passes through said first printing space,

said second rotatable cylindrical tank roll having a collection surface, said second rotatable cylindrical tank roll being rotatable about a fourth axis, such that when said second rotatable cylindrical tank roll is rotated about said fourth axis, said collection surface passes through a second

collection space which, when said second tank contains an operational quantity of a second conductive ink, is located within said quantity of second conductive ink, and said collection surface passes through a second transfer space;

said second rotatable cylindrical applicator roll being rotatable about a fifth axis, said second rotatable cylindrical applicator roll comprising a second roll printing surface, said second roll printing surface comprising at least one raised second pattern surface, each said raised second pattern surface being positioned such that upon rotation of said second cylindrical rotatable applicator roll about said fifth axis, each said raised second pattern surface passes through said second transfer space and each said raised second pattern surface passes through a second printing space defined between said second rotatable cylindrical applicator roll and said second rotatable cylindrical feed roll, said second rotatable cylindrical feed roll being rotatable about a sixth axis, said fourth axis, said fifth axis and said sixth axis being substantially parallel;

such that when said second tank contains said operational quantity of said second conductive ink and said second rotatable applicator roll, said second tank roll and said second feed roll are being rotated, said second conductive ink is transferred from said second tank to said collection surface in said second collection space, and said second conductive ink is transferred from said collection surface to said at least one raised second pattern in said second transfer space;

whereby said first semiconductor substrate surface of said semiconductor substrate passing between said second rotatable cylindrical applicator roll and said second rotatable cylindrical feed roll through said second printing space while said second tank contains said operational quantity of said second conductive ink and said second rotatable applicator roll, said second tank roll and said second feed roll are being rotated will come into contact with said second conductive ink on at least part of said raised second pattern surface, and will not come into contact with second conductive ink on substantially any of said second roll printing surface other than said raised second pattern surface, such that a second conductive ink pattern will be deposited on said first semiconductor substrate surface.

32. An apparatus as recited in claim 31, wherein at least one region of said first conductive ink pattern and at least one region of said second conductive ink pattern overlap by less than 1 cm.

33. An apparatus as recited in claim 32, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface, except for a border region around an edge of said first semiconductor substrate surface.

34. An apparatus as recited in claim 32, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface.

35. An apparatus as recited in claim 31, wherein upon rotation of said first rotatable cylindrical tank roll and said first rotatable cylindrical applicator roll, said outer surface of said first rotatable cylindrical tank roll substantially mirrors said at least one raised first pattern surface of said first rotatable cylindrical applicator roll; and

upon rotation of said second rotatable cylindrical tank roll and said second rotatable cylindrical applicator roll, said at least one collection surface of said second rotatable cylindrical tank roll substantially mirrors said at least one raised second pattern surface of said second rotatable cylindrical applicator roll.

36. An apparatus as recited in claim 31, wherein said first rotatable cylindrical feed roll comprises at least one substantially cylindrical hub having a substantially circumferential groove in which an O-ring is positioned..

37. An apparatus as recited in claim 31, further comprising a first drying region, a first conveyor, a second drying region, a second conveyor and a second surface printer,

said first conveyor being operable to convey said semiconductor substrate continuously through said first drying region and then to said second printing space,

said first drying region comprising at least one gas jet which is operable to direct a stream of gas toward said first conductive ink pattern,

said second conveyor being operable to convey said semiconductor substrate to said second drying region and then to said second surface printer after said semiconductor substrate

passes through said second printing space,

said second surface printer being operable to provide a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

38. An apparatus as recited in claim 37, further comprising at least one firing furnace and a third conveyor,

said third conveyor being operable to convey said semiconductor substrate to said at least one firing furnace after said second surface printer provides said second surface contact on said second semiconductor substrate surface.

39. An apparatus as recited in claim 31, wherein said first tank contains an operational quantity of said first conductive ink comprising from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, from about 2 weight % to about 4 weight % aluminum, and the remainder silver.

40. An apparatus as recited in claim 31, wherein said first tank contains an operational quantity of said first conductive ink comprising from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, from about 2 weight % to about 4 weight % aluminum, from about 1 weight % to about 10 weight % silica, and the remainder silver.

41. An apparatus as recited in claim 31, wherein said first tank contains an operational quantity of said first conductive ink comprising a hot melt ink.

42. An apparatus as recited in claim 41, wherein said first conductive ink comprises hexadecanol and silver.

43. An apparatus as recited in claim 31, wherein said second tank contains an operational quantity of said second conductive ink comprising from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, and the remainder aluminum.

44. An apparatus as recited in claim 31, wherein said second tank contains an operational quantity of said second conductive ink comprising from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, from about 1 weight % to about 10 weight % silica, and the remainder aluminum.

45. An apparatus as recited in claim 31, wherein said second tank contains an operational quantity of said second conductive ink comprising a hot melt ink.

46. An apparatus as recited in claim 45, wherein said second conductive ink comprises hexadecanol and aluminum.

47. An apparatus as recited in claim 31, further comprising at least one drying region and a second conveyor which is operable to convey said semiconductor substrate to said at least one drying region after said semiconductor substrate passes through said second printing space.

48. A method for applying at least one electrical contact to a semiconductor substrate, comprising:

passing a semiconductor substrate through a first printing space;

rotating about a first axis a first applicator roll having a first roll printing surface which comprises at least one raised first pattern surface, such that each said raised first pattern surface passes through a first ink space containing a first conductive ink and through said first printing space, whereby said first conductive ink is passed from each said raised first pattern surface onto a first semiconductor substrate surface of said semiconductor substrate to deposit a first conductive ink pattern on said first semiconductor substrate surface;

conveying said semiconductor substrate from said first printing space to a second printing space;

passing said semiconductor substrate through said second printing space; and

rotating about a second axis a second applicator roll having a second roll printing surface which comprises at least one raised second pattern surface, such that each said raised second pattern surface passes through a second ink space containing a second conductive ink and through

said second printing space, whereby said second conductive ink is passed from each said raised second pattern surface onto said first semiconductor substrate surface of said semiconductor substrate to deposit a second conductive ink pattern on said first semiconductor substrate surface.

49. A method as recited in claim 48, wherein at least one region of said first conductive ink pattern and at least one region of said second conductive ink pattern overlap by less than 1 cm.

50. A method as recited in claim 49, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface, except for a border region around an edge of said first semiconductor substrate surface.

51. A method as recited in claim 49, wherein said first conductive ink pattern and said second conductive ink pattern together cover substantially an entirety of said first semiconductor substrate surface.

52. A method as recited in claim 48, further comprising:

rotating about a third axis a first tank roll having a first tank roll collection surface which passes through a first collection space positioned within a first conductive ink positioned within a first tank, and passes through said first ink space, whereby said first conductive ink is passed from said first tank to said first tank roll collection surface in said first collection space, and is passed from said first tank roll collection surface to said at least one raised first pattern surface in said first ink space; and

rotating about a fourth axis a second tank roll having a second tank roll collection surface which passes through a second collection space positioned within a second conductive ink positioned within a second tank, and passes through said second ink space, whereby said second conductive ink is passed from said second tank to said second tank roll collection surface in said second collection space, and is passed from said second tank roll collection surface to said at least one raised second pattern surface in said second ink space.

53. A method as recited in claim 48, further comprising:

rotating a first feed roll about a third axis, said first printing space being defined between said first applicator roll and said first feed roll; and

rotating a second feed roll about a fourth axis, said second printing space being defined between said second applicator roll and said second feed roll.

54. A method as recited in claim 48, further comprising drying said semiconductor substrate after said passing said semiconductor substrate through said first printing space and before said passing said semiconductor substrate through said second printing space.

55. A method as recited in claim 52, wherein said drying comprises blowing at least one gas toward said first conductive ink pattern.

56. A method as recited in claim 54, further comprising drying said semiconductor substrate after said passing said semiconductor substrate through said second printing space.

57. A method as recited in claim 56, further comprising providing a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

58. A method as recited in claim 57, further comprising firing said semiconductor substrate after said providing said second surface contact.

59. A method as recited in claim 48, further comprising drying said semiconductor substrate after said passing said semiconductor substrate through said second printing space.

60. A method as recited in claim 48, further comprising providing a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

61. A method as recited in claim 60, further comprising firing said semiconductor substrate after said providing said second surface contact.

62. A method as recited in claim 48, wherein said first conductive ink comprises from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, from about 2 weight % to about 4 weight % aluminum, and the remainder silver.

63. A method as recited in claim 48, wherein said first conductive ink comprises a hot melt ink.

64. A method as recited in claim 63, wherein said first conductive ink comprises hexadecanol and silver.

65. A method as recited in claim 48, wherein said second conductive ink comprises from about 20 weight % to about 35 weight % of a solvent, about 2 weight % of a binder, and the remainder aluminum.

66. A method as recited in claim 48, wherein said second conductive ink comprises a hot melt ink.

67. A method as recited in claim 66, wherein said second conductive ink comprises hexadecanol and aluminum.

68. A method as recited in claim 48, wherein said semiconductor substrate comprises a diode.

69. A method as recited in claim 48, wherein said semiconductor substrate comprises polycrystalline silicon.

70. A method as recited in claim 48, wherein said semiconductor substrate comprises single crystal silicon.

71. A method for applying at least one electrical contact to a semiconductor substrate, comprising:

passing a semiconductor substrate through a first printing space; and

rotating about a first axis a first applicator roll having a first roll printing surface which comprises at least one raised first pattern surface, such that each said raised first pattern surface passes through a first ink space containing a first conductive ink comprising a hot melt ink, and through said first printing space, whereby said first conductive ink is passed from at least one said raised first pattern surface onto a first semiconductor substrate surface of said semiconductor substrate to deposit a first conductive ink pattern on said first semiconductor substrate surface.

72. A method as recited in claim 71, wherein said first conductive ink comprises hexadecanol and silver.

73. A method as recited in claim 71, further comprising drying said semiconductor substrate after said passing said semiconductor substrate through said first printing space

74. A method as recited in claim 73, wherein said drying comprises blowing at least one gas toward said first conductive ink pattern.

75. A method as recited in claim 71, further comprising providing a second surface contact on a second semiconductor substrate surface of said semiconductor substrate.

76. A method as recited in claim 73, further comprising firing said semiconductor substrate after said providing said second surface contact.

77. A method as recited in claim 71, wherein said semiconductor substrate comprises a diode.

78. A method as recited in claim 71, wherein said semiconductor substrate comprises polycrystalline silicon.

79. A method as recited in claim 71, wherein said semiconductor substrate comprises single crystal silicon.